6

REHABILITATION OF NONSTRUCTURAL MECHANICAL AND ELECTRICAL COMPONENTS

6.0 INTRODUCTION

Nonstructural mechanical and electrical components are often vulnerable to seismic damage in moderate to large earthquakes. Damage to mechanical and electrical components can impair building functions that may be essential to life safety. This chapter presents common techniques for mitigating seismic damage of the following typical mechanical and electrical components:

- Mechanical and electrical equipment
- Ductwork and piping
- Elevators
- Emergency power systems
- Hazardous material storage systems
- Communication systems
- Computer equipment

6.1 MECHANICAL AND ELECTRICAL EQUIPMENT

Large equipment that is unanchored or inadequately anchored can slide during an earthquake and damage utility connections. Tall, narrow units may also be vulnerable to overturning. Positive mechanical anchorages (Figure 6.1a) will prevent seismic damage.

Electrical equipment frequently is tall and narrow and may overturn and slide, causing damage to internal instruments and utility connections. This type of equipment can be secured against sliding or rocking in many ways depending on the location of the units relative to adjacent walls, ceilings, and floors (Figure 6.1b). In all cases, the capacity of the wall to resist the seismic loads imposed by the connected equipment must be verified.

Mechanical or electrical equipment located on vibration isolators may be particularly vulnerable to being shaken off the isolator supports. Rehabilitation to mitigate the potential for damage involves either replacing the vibration isolation units or installing rigid stops. Vibration isolation units that also provide lateral seismic resistance are available from isolator manufacturers and these units (Figure 6.1c) can be installed in place of the existing isolators. Alternatively, rigid stops designed to prevent excessive lateral movement of the equipment can be installed on the existing foundation (Figure 6.1d and e). A sufficient gap needs to be provided between the stop and the equipment to prevent the transmission of vibrations through the stops. Where equipment is tall relative to its width, stops in the vertical direction are required to prevent overturning. The equipment itself, its attachments to the isolators or support rails, and the rails themselves can be points of weakness that need to be assessed and strengthened where required.

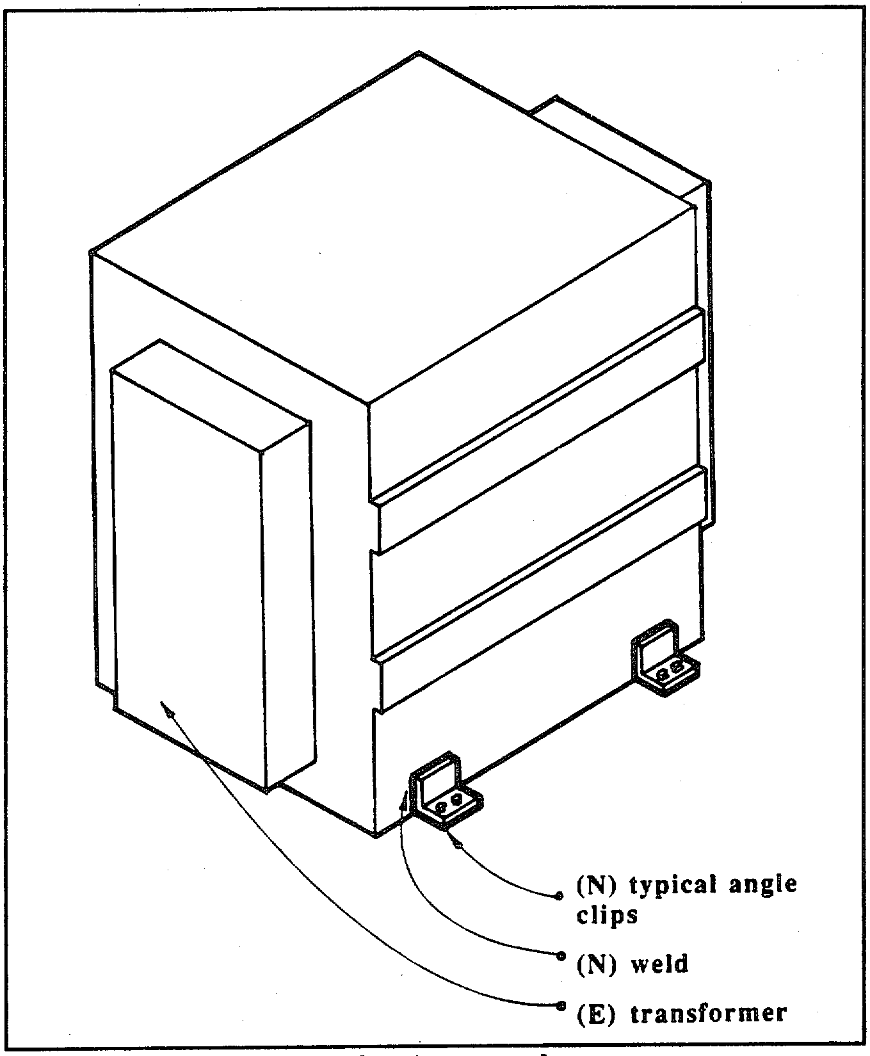

FIGURE 6.1a Typical detail of equipment anchorage.

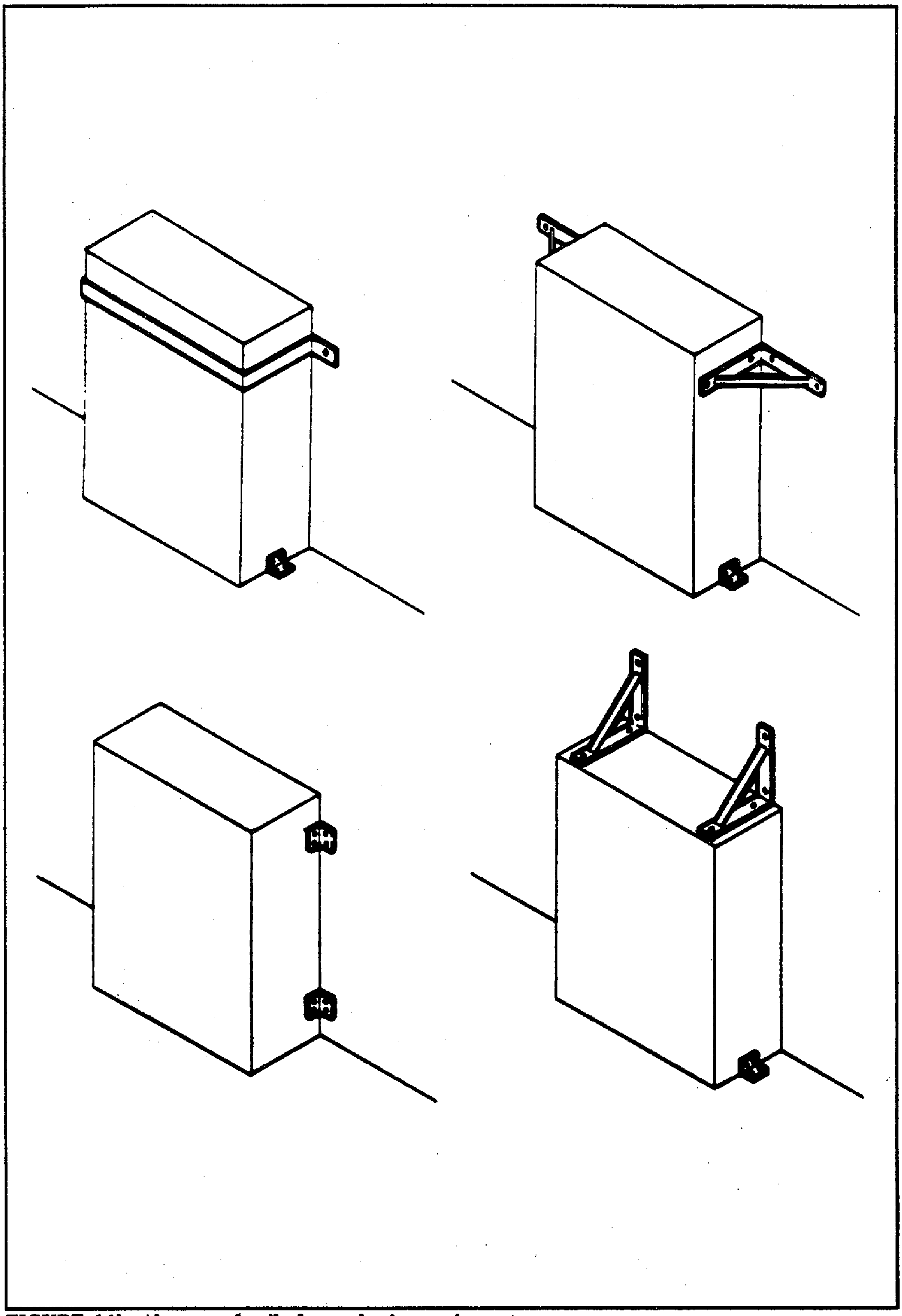

FIGURE 6.1b Alternate details for anchoring equipment.

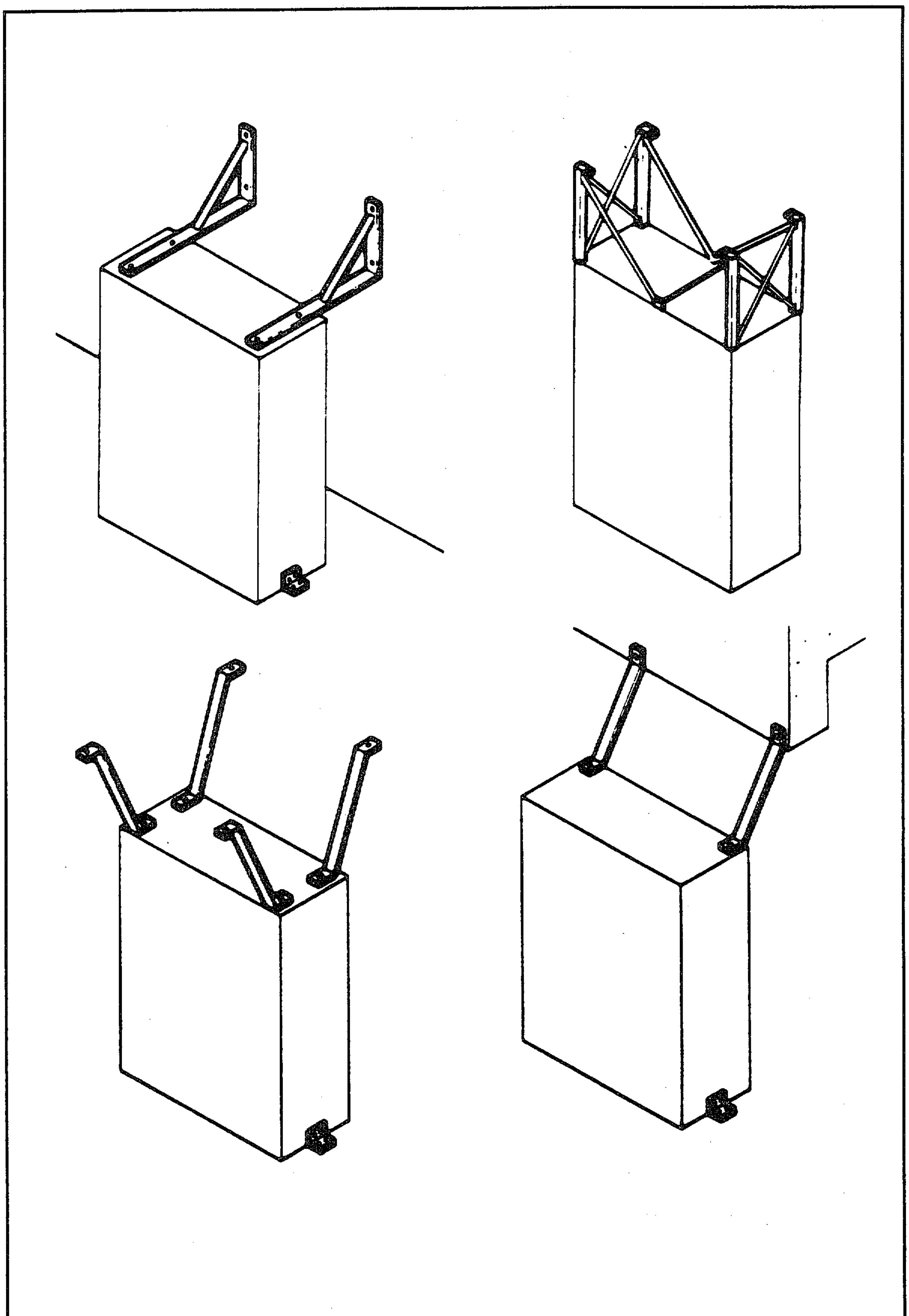

FIGURE 6.1b continued.

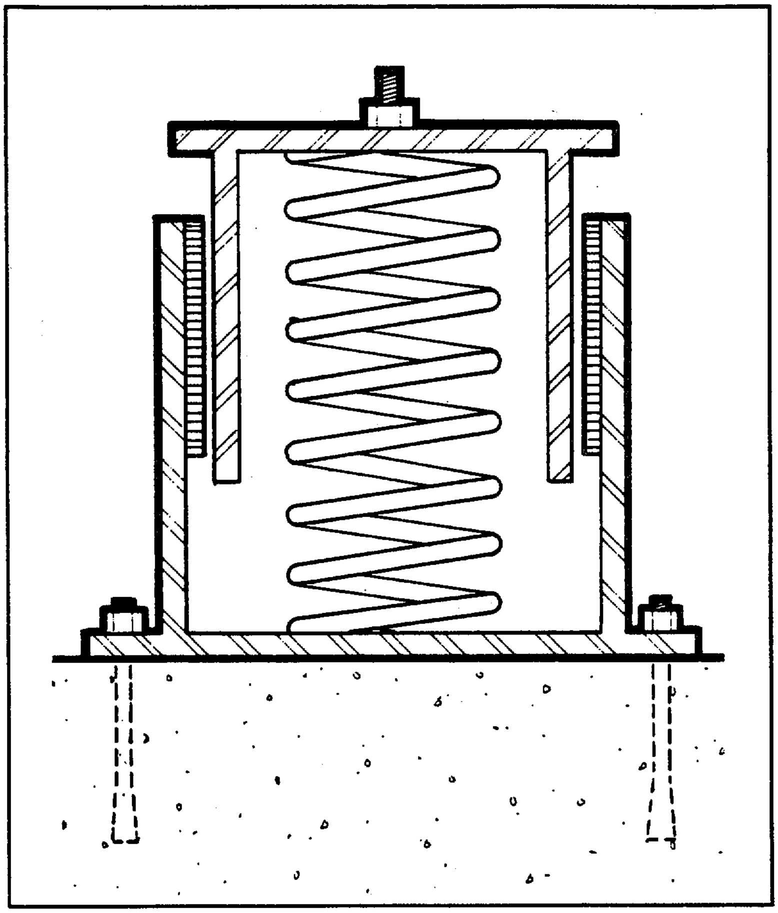

FIGURE 6.1c Prefabricated vibration isolation assembly with lateral seismic stops.

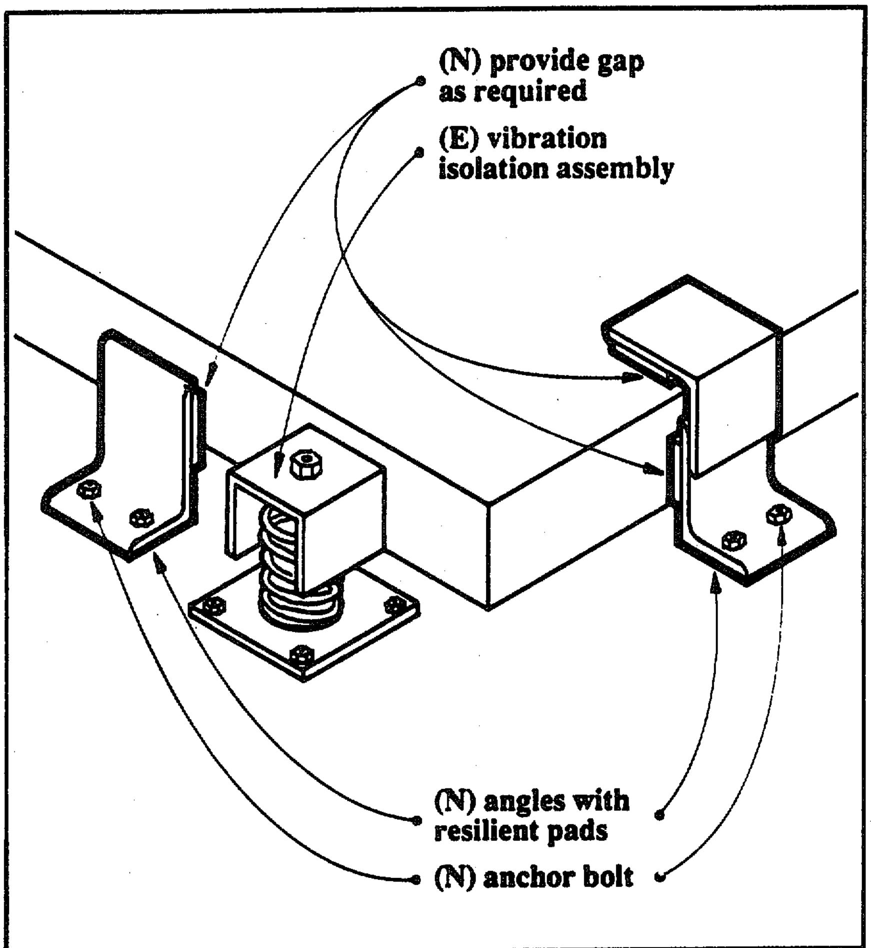

FIGURE 6.1d Seismic restraints added to existing equipment with vibration isolation.

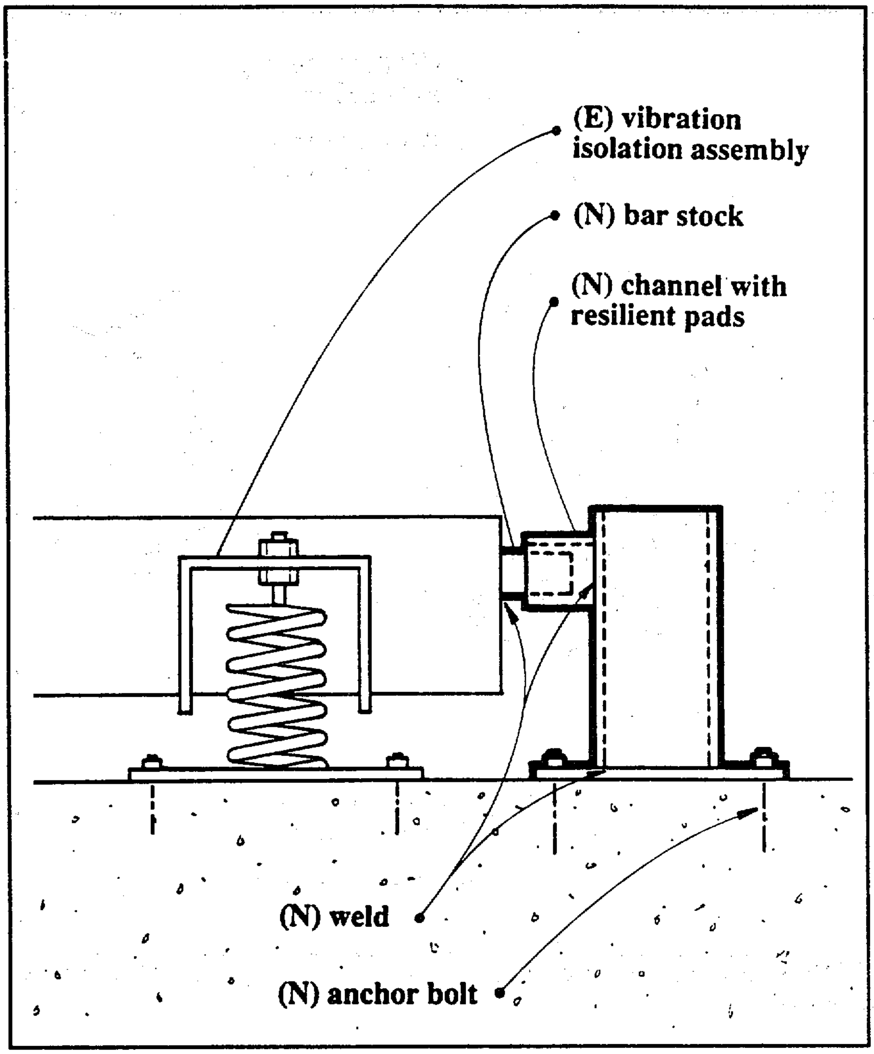

FIGURE 6.1e Multidirectional seismic restraint.

Suspended mechanical or electrical equipment may sway during an earthquake, damaging utility connections and the vertical support components. This equipment should be braced to prevent swaying (Figure 6.1f).

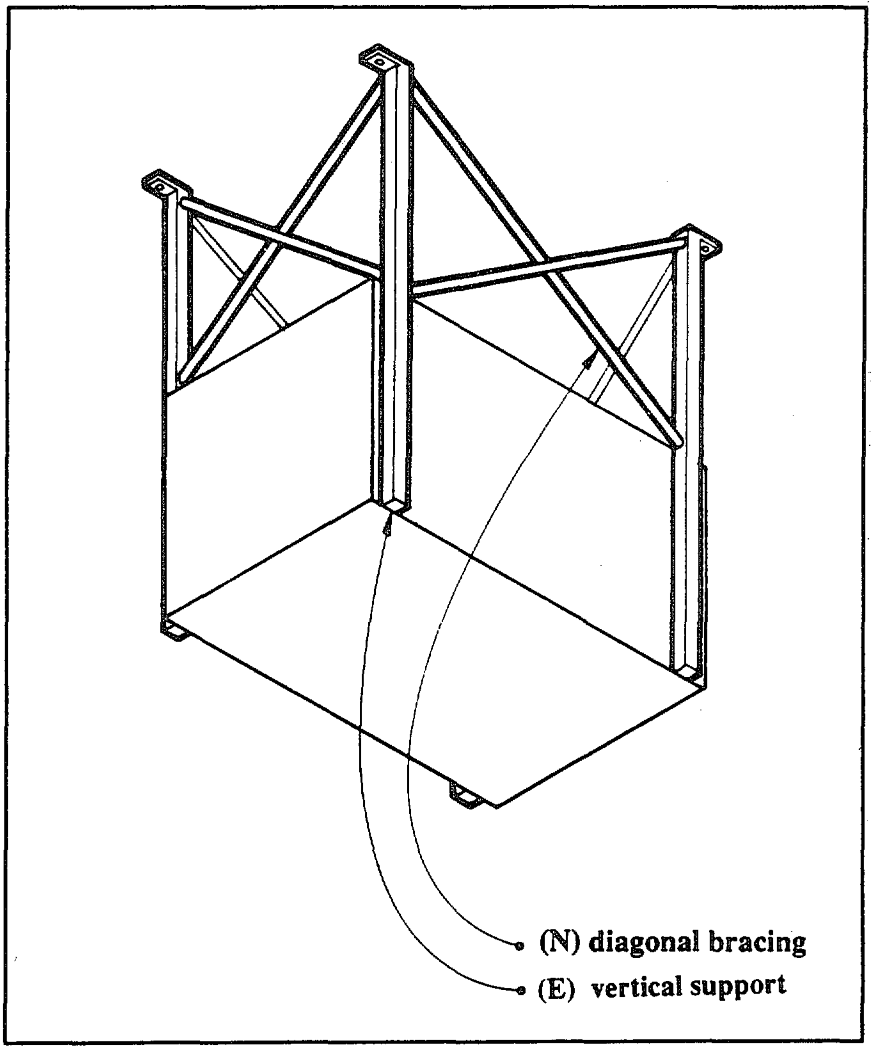

FIGURE 6.1f Typical bracing for suspended equipment.

Water heaters are tall, heavy, narrow components that, if unanchored, are vulnerable to damage in an earthquake. Sliding or overturning of water heaters may result in broken water and gas lines. Water heaters should be anchored as shown in Figure 6.1g, and flexible gas lines should be installed with a sufficient loop to allow the heater some movement without stressing the gas lines.

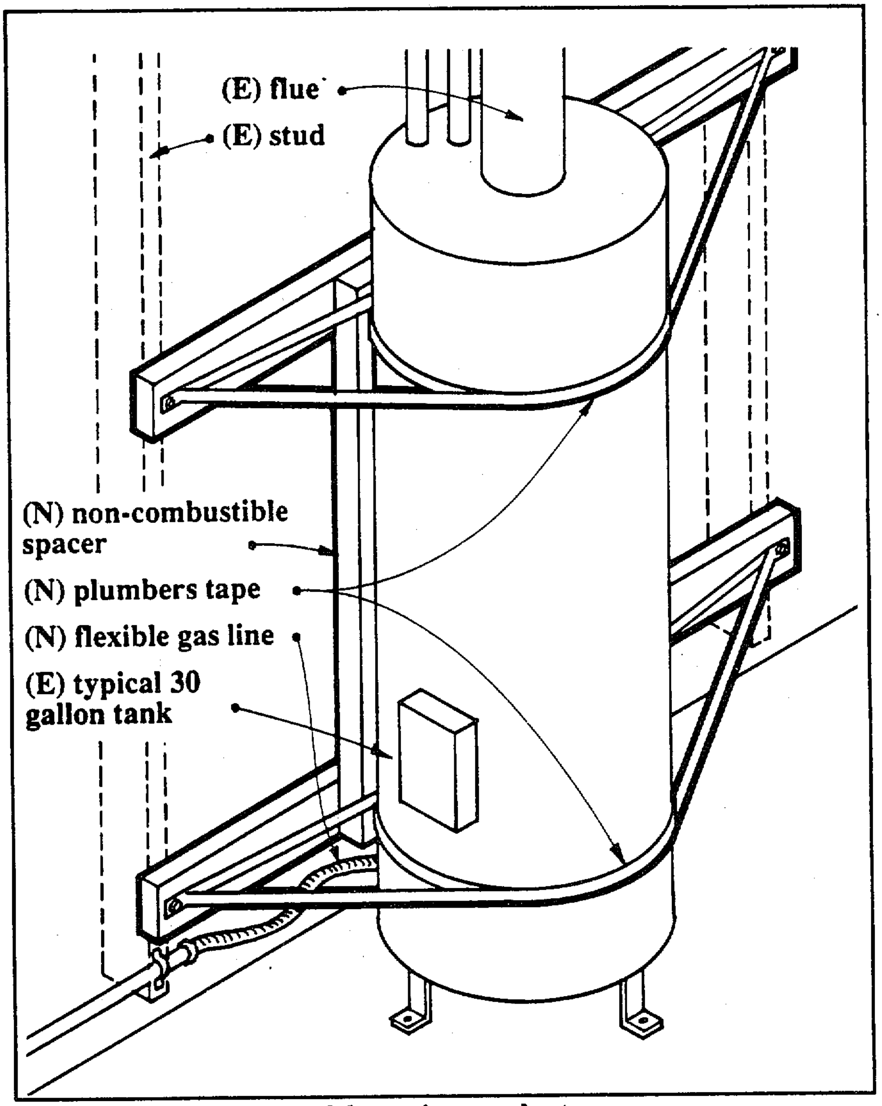

FIGURE 6.1g Strapping of domestic water heater.

6.2 DUCTWORK AND PIPING

Seismic retrofit of ductwork and piping primarily consists of providing lateral sway braces. The Sheet Metal and Air-Conditioning Contractors National Association (SMACNA) has published guidelines for the design of seismic restraints of new mechanical systems and plumbing piping systems (September 1982) that can also be used for rehabilitation of existing systems. These guidelines were developed for use in areas of relatively high seismicity and engineering judgment should be utilized in their application elsewhere. The SMACNA guidelines for seismic bracing of ductwork recommend that:

1. All rectangular ducts 6 square feet in area and greater and round ducts 28 inches in diameter and larger should be seismically braced.

2. Transverse braces should be installed at a maximum of 30 feet on center, at each duct turn, and at each end of a duct run.

3. Longitudinal braces should be installed at a maximum of 60 feet on center.

4. No bracing is required if the top of a duct is suspended 12 inches or less from the supporting structural member and the suspension straps are attached to the top of the duct.

The SMACNA guidelines for seismic bracing of piping recommend that:

1. Braces for all pipes 2-1/2 inches in diameter and larger (and also for smaller piping used for fuel gas, oil, medical gas, and compressed air and smaller piping located in boiler rooms, mechanical equipment rooms, and refrigeration machinery rooms).

2. Transverse braces should be installed at a maximum of 40 feet on center.

3. Longitudinal braces should be installed at a maximum of 80 feet on center.

4. Thermal expansion and contraction forces, where present, must be considered in the layout of transverse and longitudinal braces.

5. Flexibility should be provided where pipes pass through seismic or expansion joints.

Figures 6.2a through 6.2c show typical seismic brace details for ducting. Duct diffusers also should be positively attached with mechanical anchors to rigid ducts or secured with wires to the floor above when connected to flexible ducts. Figures 6.2d through 6.2g show typical details for installing seismic braces for piping.

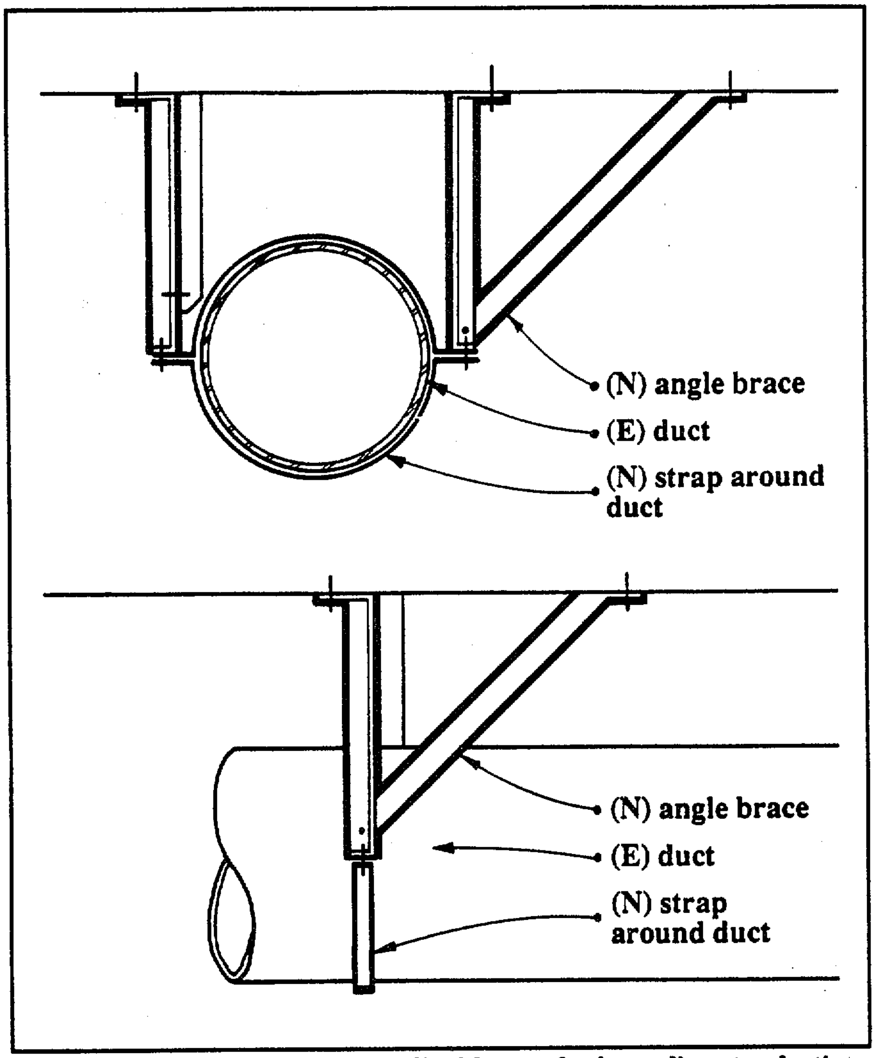

FIGURE 6.2a Lateral and longitudinal braces for large-diameter ducting.

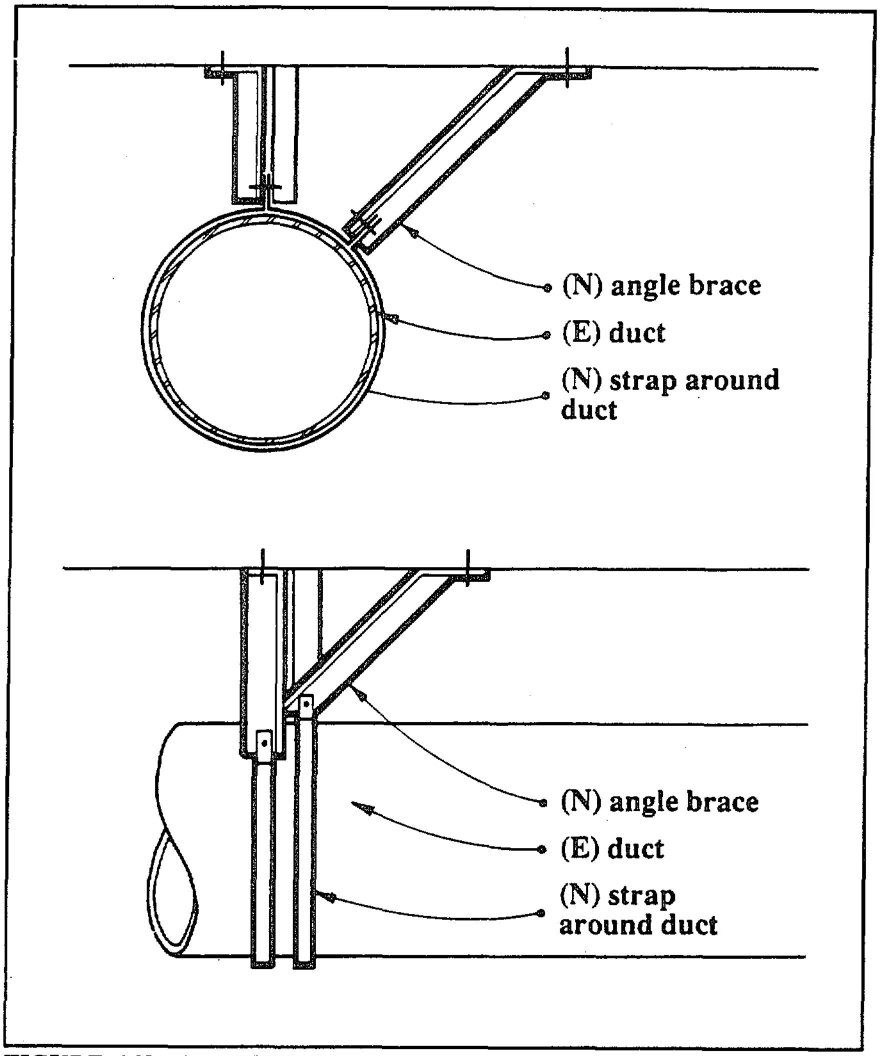

FIGURE 6.2b Lateral and longitudinal braces for small-diameter ducting.

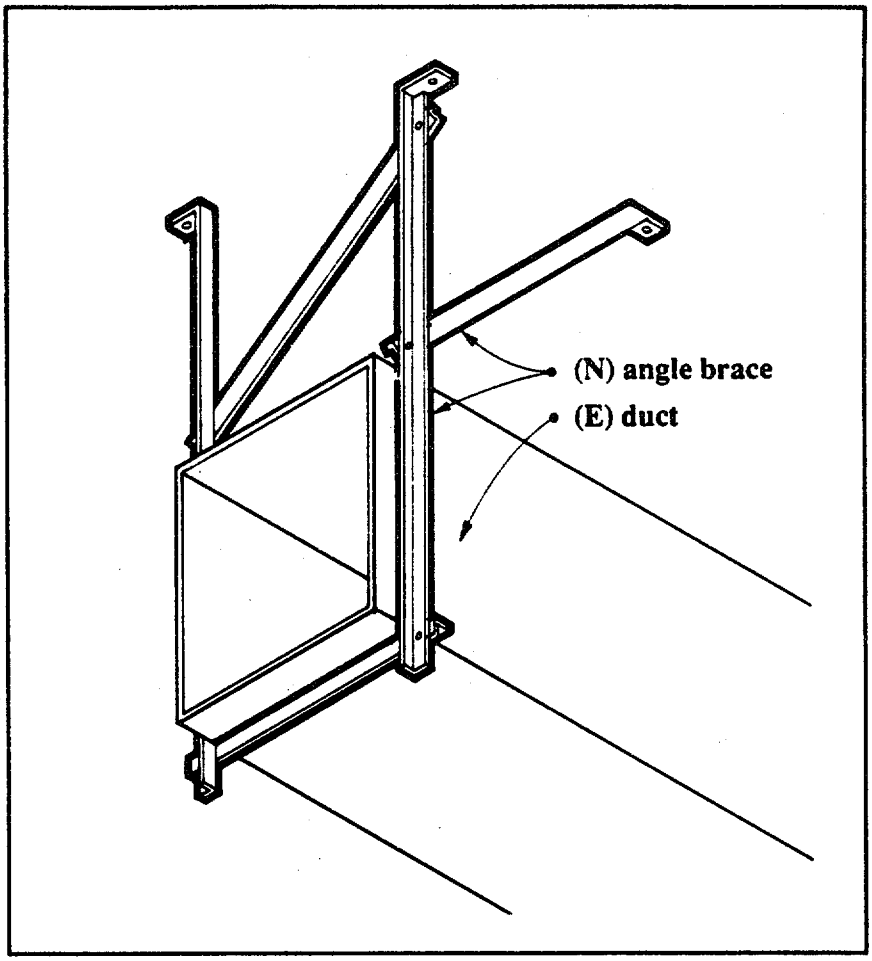

FIGURE 6.2c Lateral and longitudinal braces for rectangular ducting.

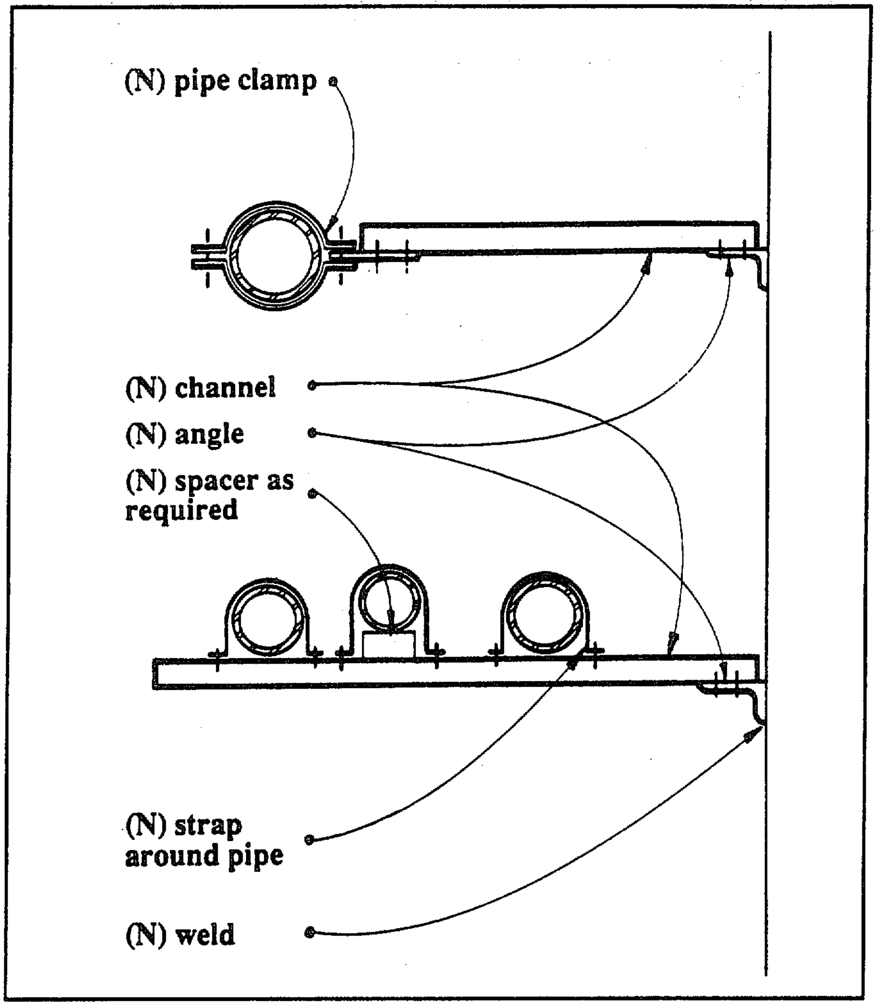

FIGURE 6.2d Lateral braces for piping.

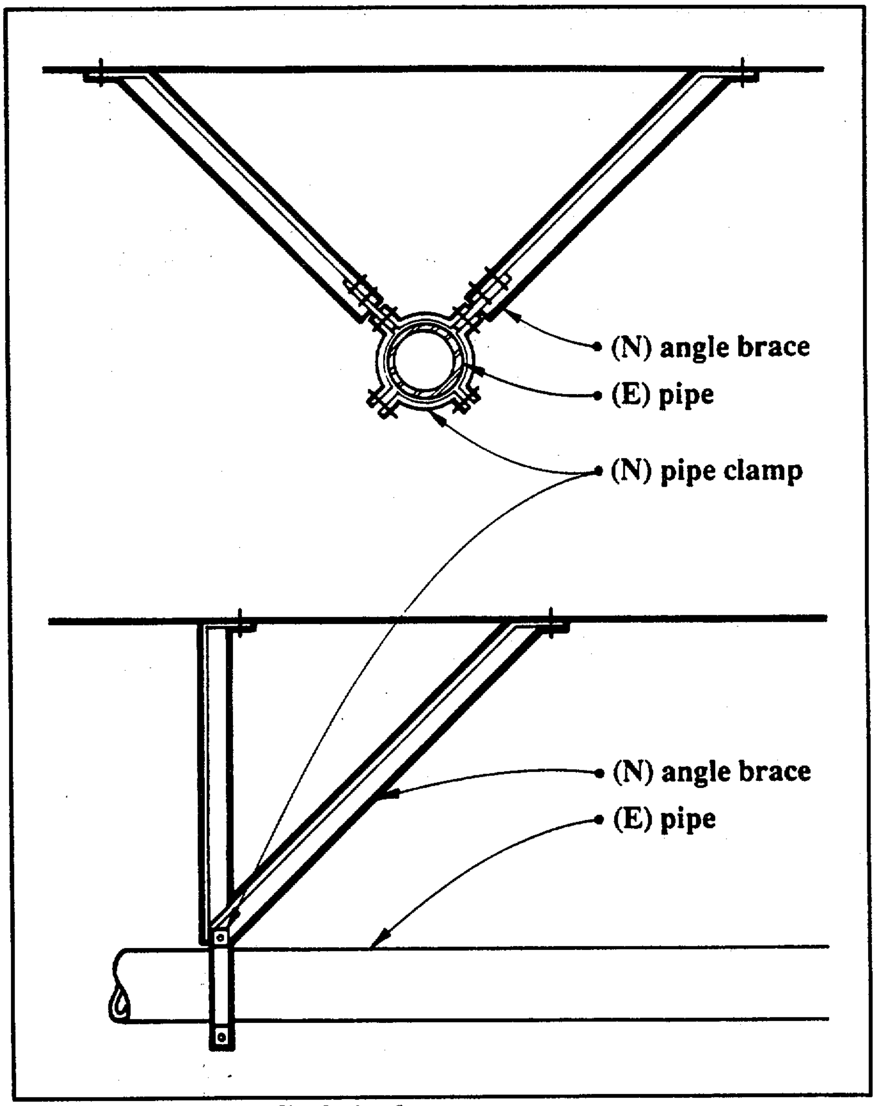

FIGURE 6.2e Longitudinal pipe brace.

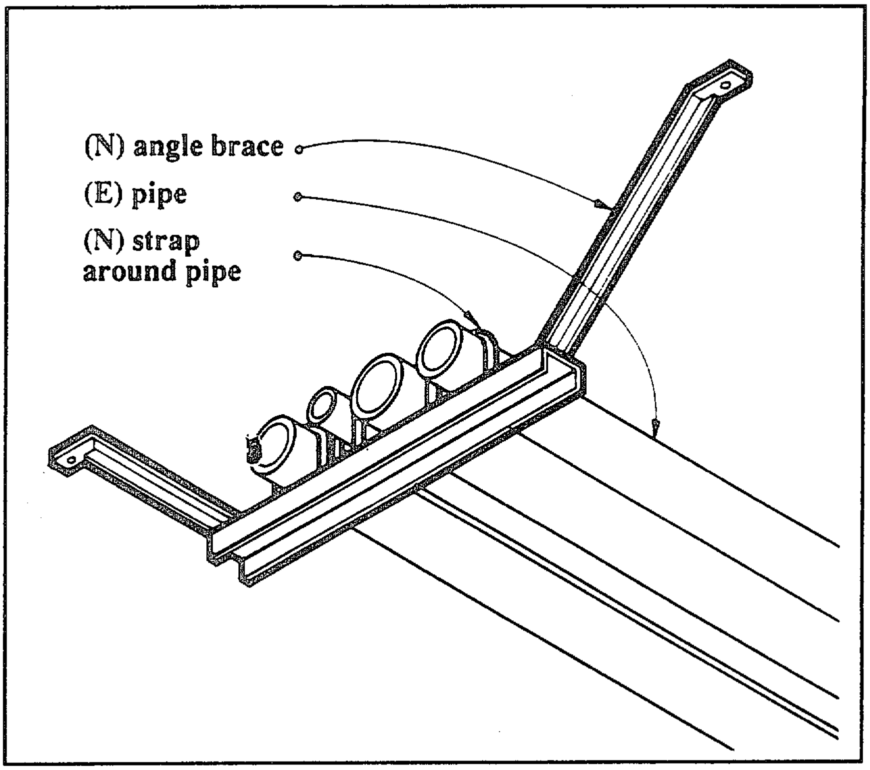

FIGURE 6.2f Lateral brace for multiple pipes.

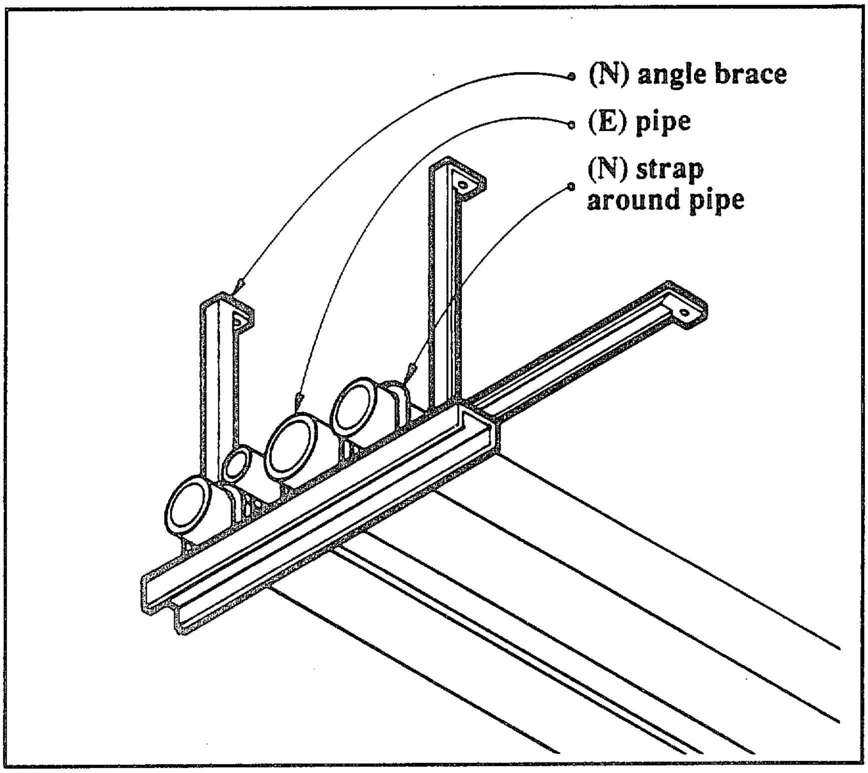

FIGURE 6.2g Longitudinal brace for multiple pipes.

6.3 ELEVATORS

Elevator machinery and controller units should be anchored like other mechanical and electrical equipment to prevent the units from sliding or toppling. Rope retainer guards should be provided on sheaves to inhibit displacement of wire ropes. Snag points created by rail brackets should be provided with guards so that compensating ropes or chains, governor ropes, suspension ropes, and traveling cables will not snag. Retainer plates should be added to the top and bottom of the cars and counterweights to prevent them from becoming dislodged from the rails. Seismic switches should be installed to provide an electrical alert or command for the safe automatic emergency operation of the elevator system and to detect lateral motion of the counterweight. For more information on the requirements for elevator seismic safety refer to ANSI 17.1, *Safety Codes for Elevators and Escalators*.

6.4 EMERGENCY POWER SYSTEMS

Although emergency power systems typically containing batteries, motor generators, fuel tanks, transformers, switchgear, and control panels are designed to be activated in the event of an emergency, many are inadequately protected from earthquake forces.

Batteries are frequently stored in racks as shown in Figure 6.4a, and structural members should be installed to restrain the batteries to the racks, the racks should be braced, and adequate anchorages should be provided to carry the lateral loads. Foam spacers also should be fitted snugly between the batteries to prevent them from impacting each other.

Motor generators typically are mounted on vibration isolators, and these units should have seismic stops installed as shown in Figures 6.1d or 6.1e. Fuel tanks frequently are mounted on legs to facilitate gravity feed of the fuel, and these tanks should be braced as shown in Figure 6.4b and provided with adequate anchorage. Flexible fuel piping with adequate loops also should be installed both at the fuel tank and at the motor generator, transformers, switchgear, and control panels should be anchored as shown in Figure 6.1b.

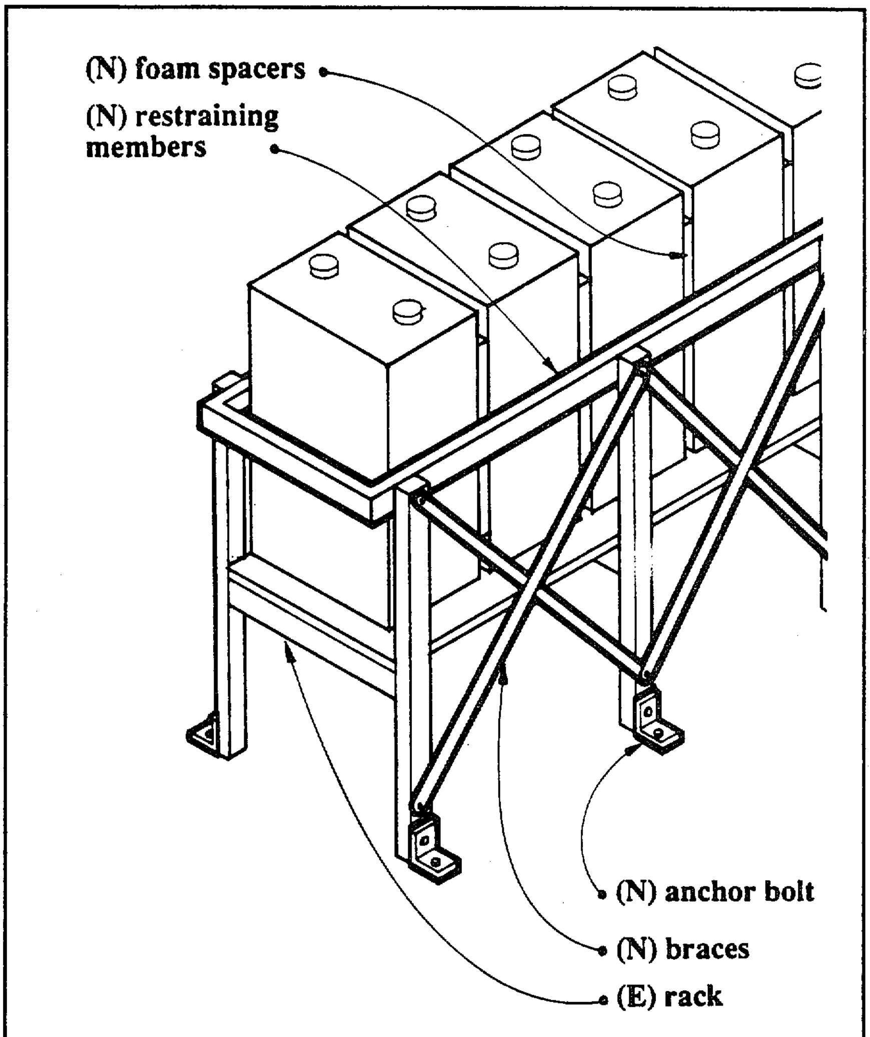

FIGURE 6.4a Bracing of existing battery racks.

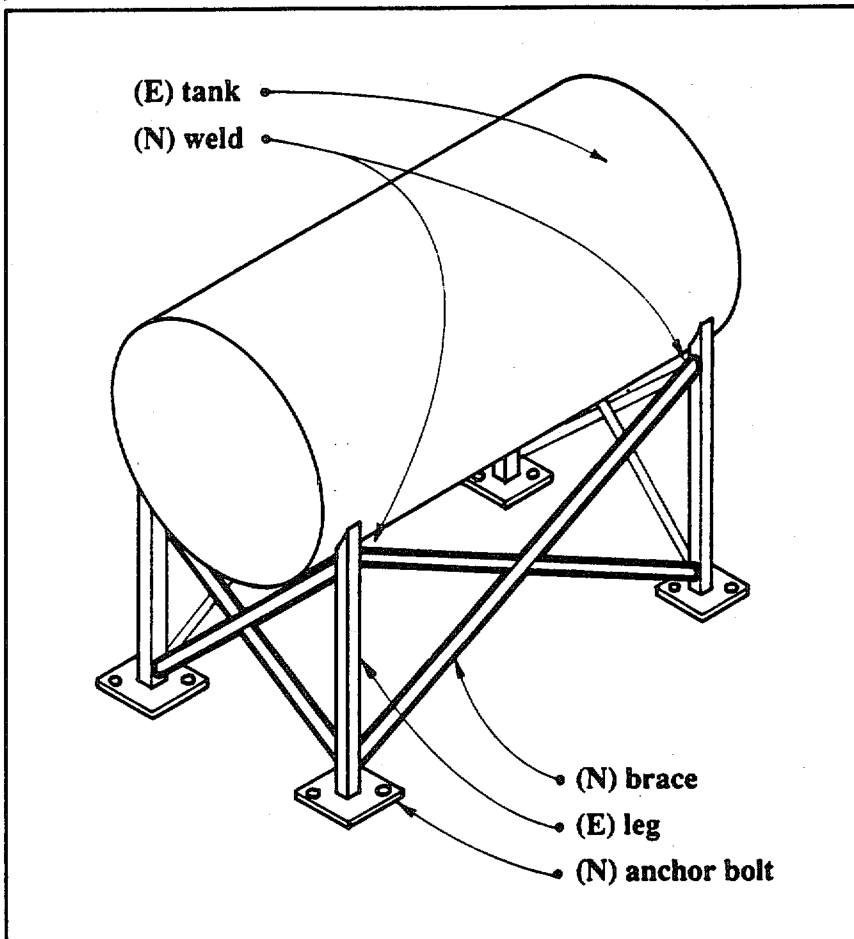

FIGURE 6.4b Bracing of horizontal tank.

6.5 HAZARDOUS MATERIAL STORAGE SYSTEMS

Seismic-activated shutoff valves should be installed on hazardous materials supply lines. These lines also should be adequately braced as shown in Figures 6.2e and 6.2f and should be provided with flexible connections at storage tanks. Bottles of laboratory chemicals should be prevented from falling by using elastic straps or shelf lips as shown in Figure 6.5a. Liquid oxygen and similar pressurized tanks also should be restrained as indicated in Figure 6.5b.

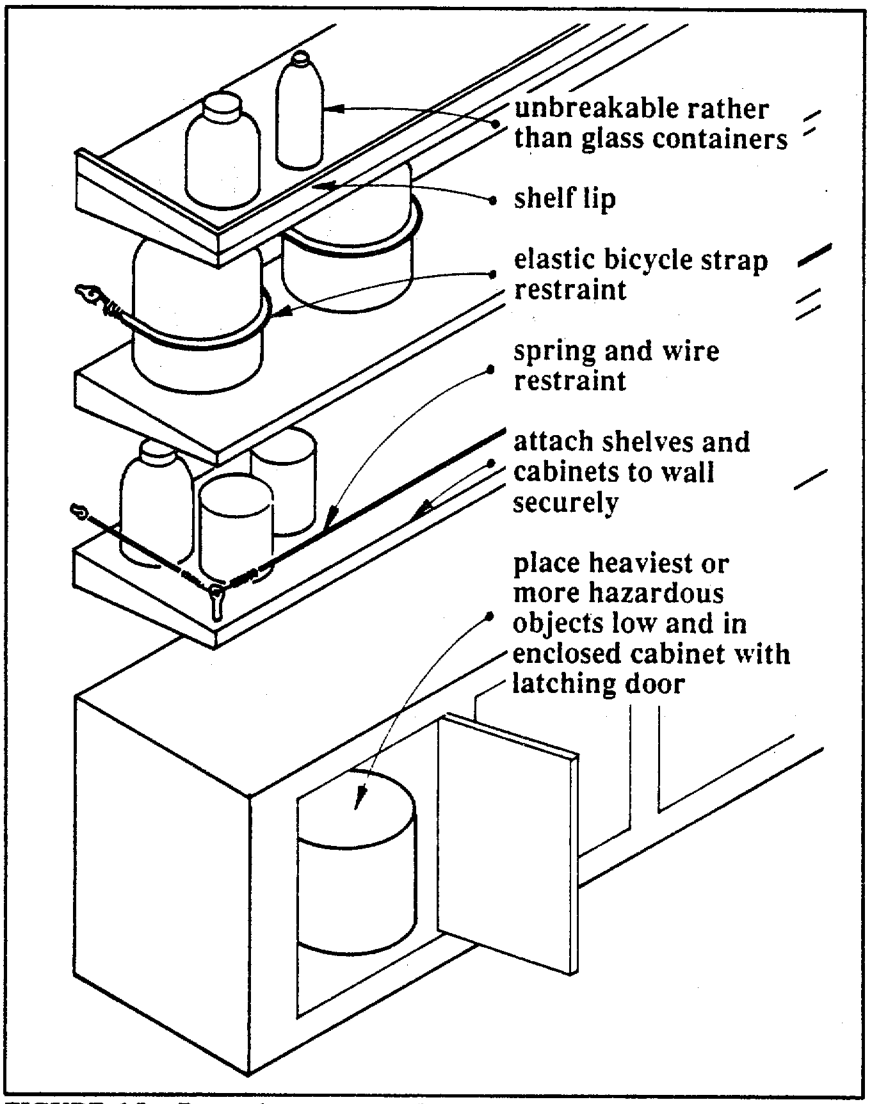

FIGURE 6.5a Protective measures for hazardous materials.

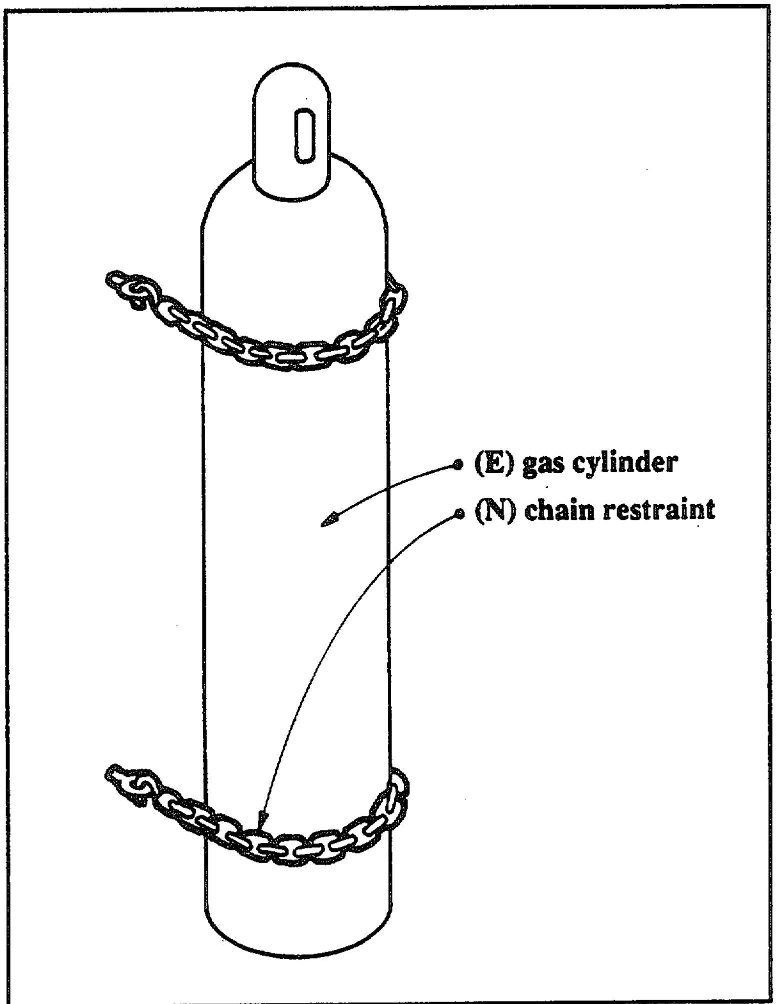

FIGURE 6.5b Anchorage detail for pressurized tanks.

6.6 COMMUNICATIONS SYSTEMS

The operation of communication systems following an earthquake is of vital importance to individuals, communities, federal agencies, and private businesses that depend on them to aid in assessing damage and responding to problems.

Telephone communications equipment consists of input and output data processing units, disk drives, central computers, and remote regional and central switching units, much of which is located on raised access floors; this computer type equipment is discussed in Sec. 6.7. Remote switching units not located on raised floors should be secured like other mechanical and electrical equipment as discussed in Sec. 6.1.

Essential facilities such as hospitals and fire and police stations that must have communication capabilities in the event of an earthquake should have backup external and internal communication systems. Radio equipment should be secured to prevent sliding or toppling. Desk top equipment also should be secured or tethered to prevent falling.

6.7 COMPUTER EQUIPMENT

Computer equipment vulnerable to seismic damage includes electronic data processing equipment such as mainframes, peripherals, telecommunications cabinets, and tape and disk storage units. Seismic rehabilitation to protect computer equipment is different from that required for other mechanical and electrical equipment for several reasons: (1) computer equipment typically is located on raised access floors that complicate traditional anchorage techniques and may amplify seismic loads, (2) computer equipment design is rapidly evolving and advancing, units frequently are replaced or rearranged, and (3) some computer equipment may be sensitive to high-frequency vibrations such as those that may be caused by ground shaking.

The remainder of this section briefly identifies rehabilitation techniques for data processing equipment and tape and disk storage racks. For more information on the subject, refer to *Data Processing Facilities: Guidelines for Earthquake Hazard Mitigation* (Olson, 1987), which provides detailed seismic design recommendations for new computer facilities and the rehabilitation of existing facilities.

Electronic data processing (EDP) equipment typically is located on raised access floors; hence, the traditional techniques of anchoring electrical equipment to the floor are complicated by the fact that the anchorage needs to pass through the access floor to the subfloor. This reduces the access to the space beneath the raised floor and greatly reduces the flexibility to rearrange and replace equipment. Some dynamic tests of EDP equipment also have shown that certain vibration-sensitive equipment may be more prone to seismic damage if it is rigidly anchored to the building and is subjected to high-frequency seismic ground motions than if the equipment is free to slide on the access floor. However, if EDP units are unrestrained, they may slide into structural walls or adjacent equipment or their support feet may slide into an access floor penetration, and the unit will topple.

Two general solutions may be used to reduce the potential for seismic damage of EDP equipment: rigidly restraining the equipment or allowing the equipment to slide. Rigid restraints (Figure 6.7a) may be appropriate for equipment that is not vibration-sensitive, is not likely to be relocated, or is tall and narrow (and, hence, susceptible to toppling). Air-handling units, modem cabinets, and power distribution units fall into this category. Tall, flexible equipment such as modem cabinets may require stiffening or bracing near the top. If anchored only at the base, the seismic motions at the top of the units may be significantly amplified and may result in equipment damage. Figure 6.7b shows a detail that will prevent toppling but does not transmit high-frequency ground shaking to the unit.

Equipment that is vibration sensitive or is likely to require frequent relocation can be isolated to reduce the potential for seismic damage. Some of the considerations necessary for isolating equipment include protecting the equipment from sliding to prevent a supporting foot or caster from falling into an opening in the access floor (provided for cable penetrations). This can be prevented by tethering the equipment to the subfloor (Figure 6.7c) so that the equipment cannot slide far enough to impact other equipment or walls or to fall into a penetration. Precautions should be considered for tall equipment restrained with a tether to prevent the equipment from reaching the end of the tether, which may cause the equipment to overturn. Floor penetrations also can be provided with guards (Figure 6.7c) that will prevent the equipment feet from entering. Adjacent equipment either should be separated by about 1 foot to prevent potential pounding or should be strapped together (Figure 6.7d) so that the separate pieces move as a unit.

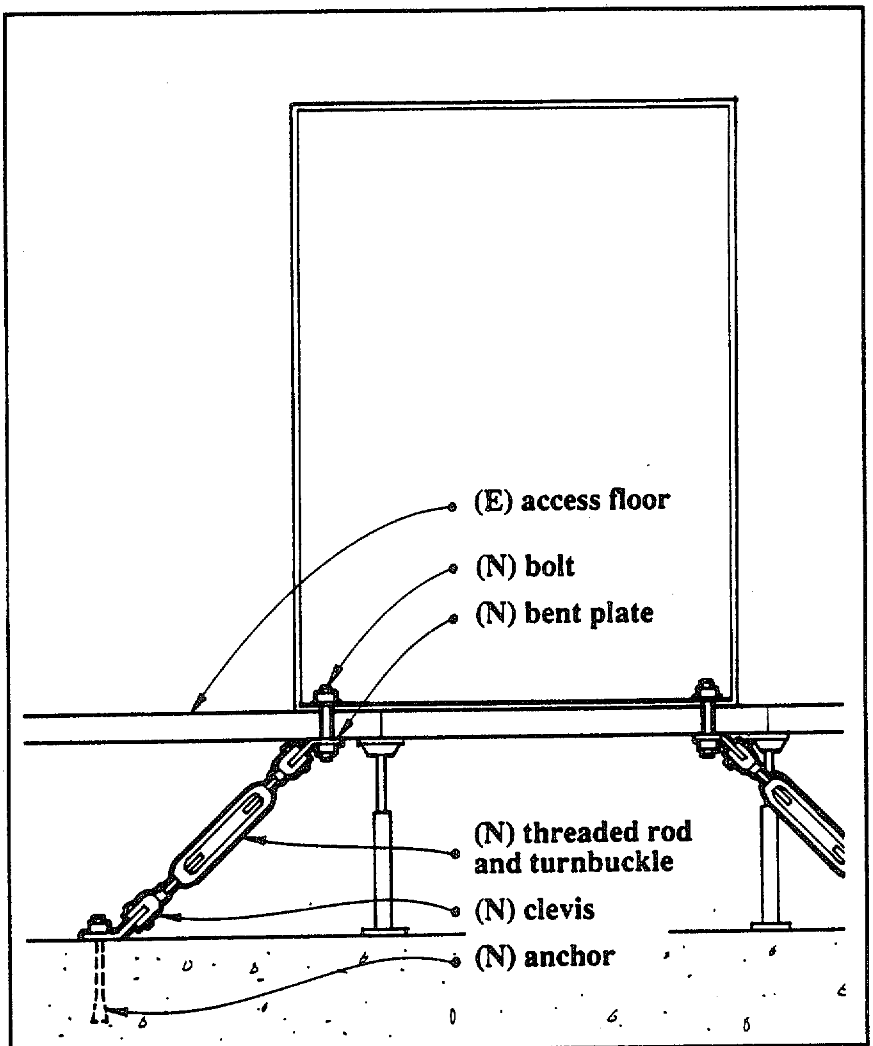

FIGURE 6.7a Rigid anchorage of computer equipment.

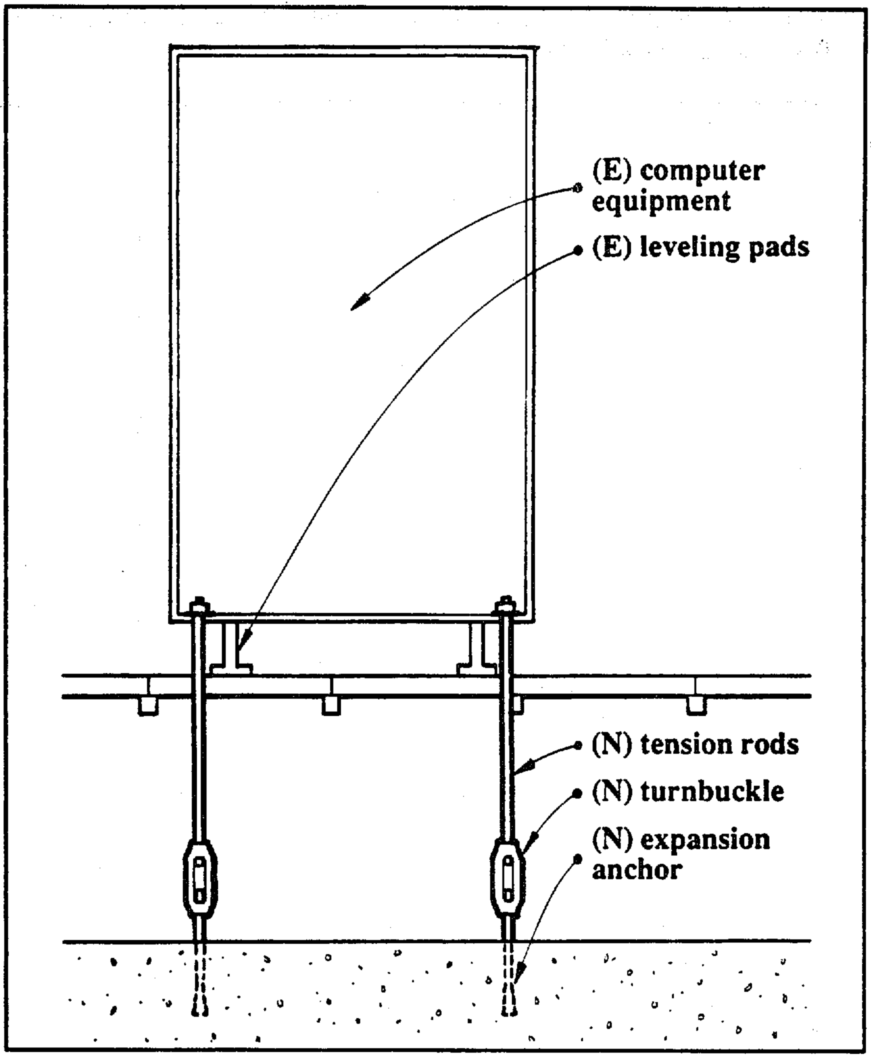

FIGURE 6.7b Flexible anchorage of computer equipment.

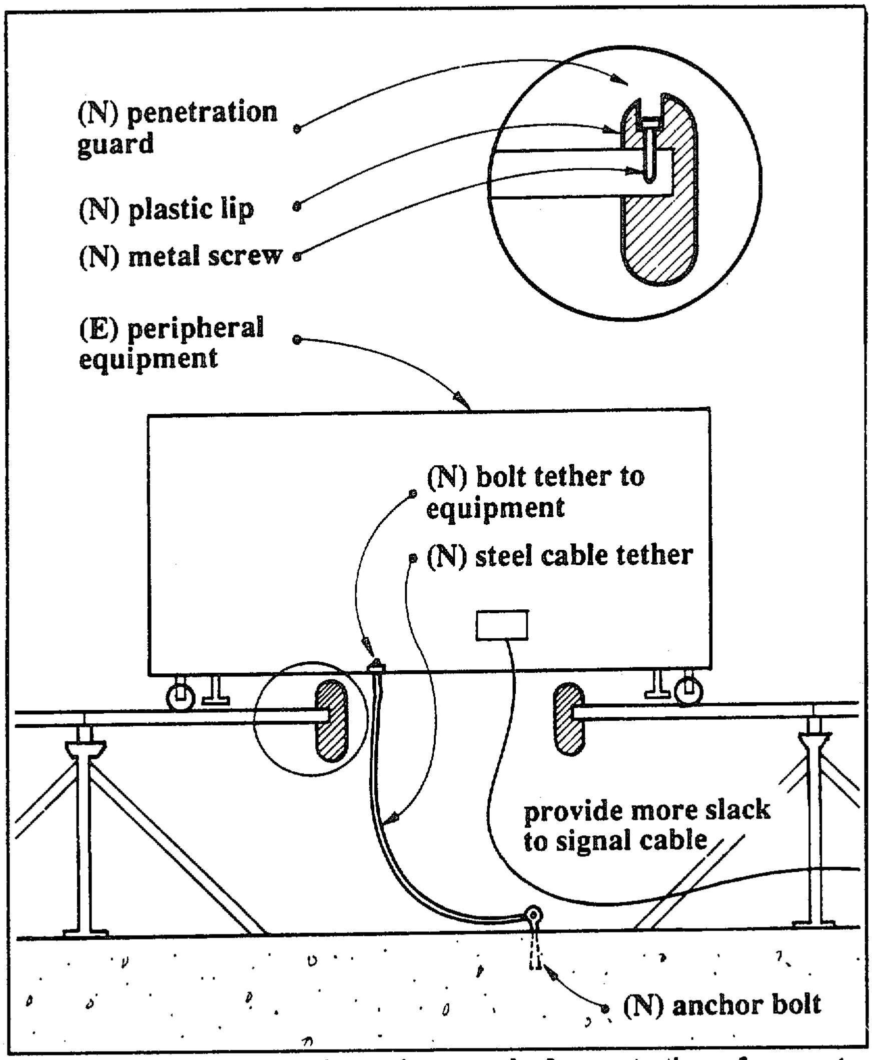

FIGURE 6.7c Tether and opening guards for protection of computer equipment.

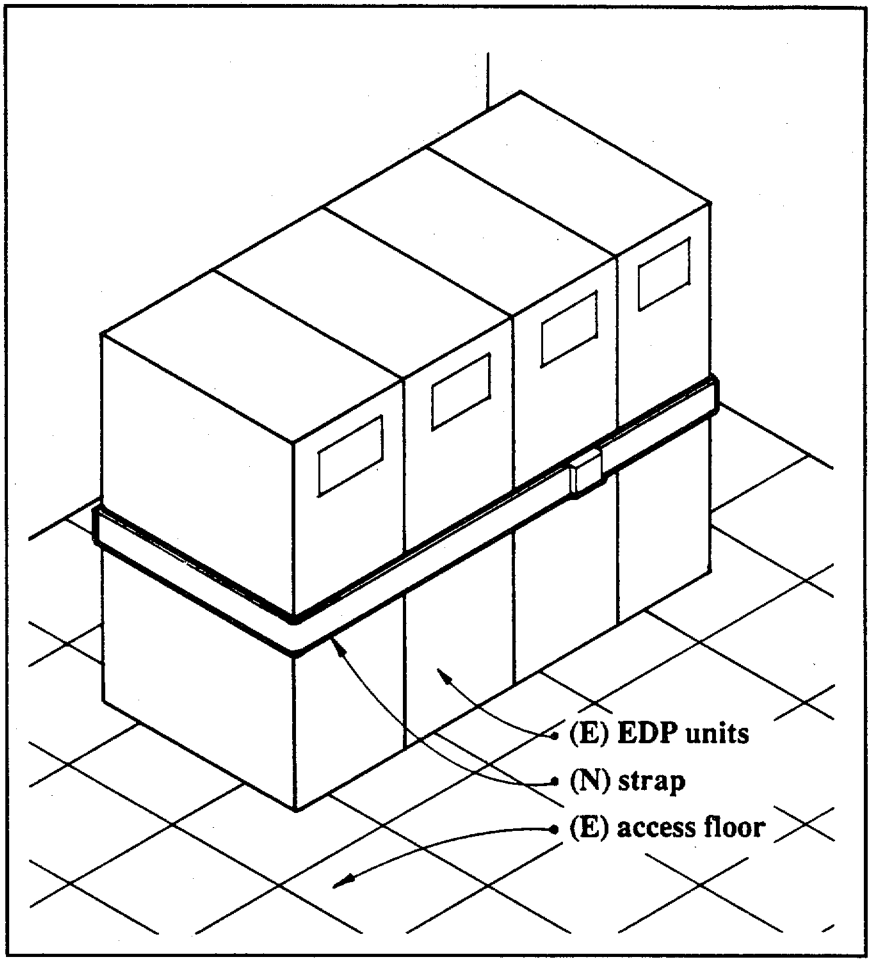

FIGURE 6.7d Strapping of electronic data processing units.